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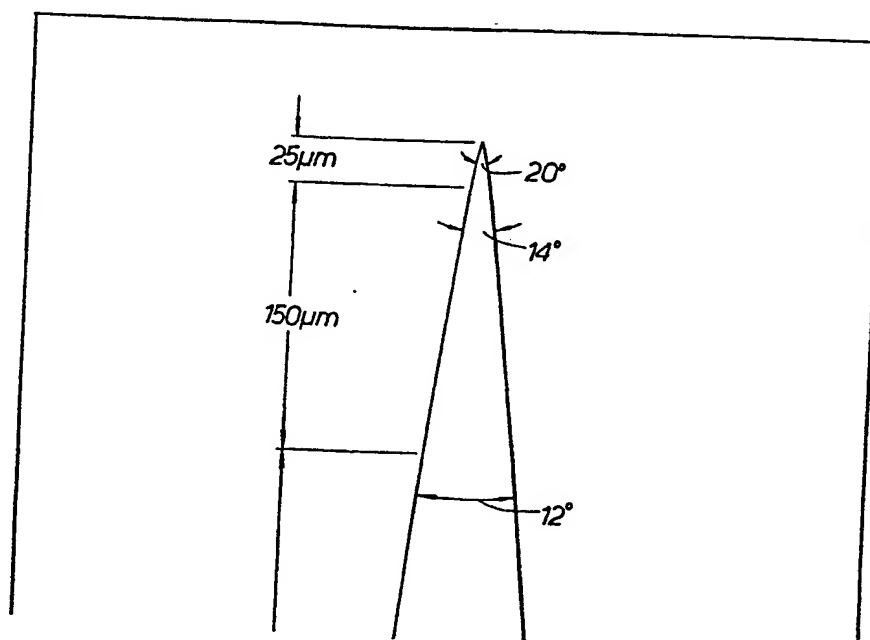
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## (54) Razor blades

(57) A razor blade edge tip has a cross-sectional shape which, up to a distance  $40\text{ }\mu\text{m}$  from the extreme edge is defined by the equation  $w = ad^n$ , in which  $w$  is the tip chord thickness in  $\mu\text{m}$  at a distance  $d$  from

the extreme edge;  $a$  is a factor of proportionality not greater than 0.8, and  $n$  is an exponent having a value in the range 0.65 to 0.75.

This results in a tip shape which is relatively thick very close to the edge but whose overall crosssection is narrow, compared with known tip shapes.



PATENTS ACT 1977

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The following corrections were allowed under Section 117 on 19 December 1984:

Front page, Heading (72) Inventors *for* Romauld Kozlowski *read* Romuald Kozlowski

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 21 January 1985

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FIG. 1.

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SPECIFICATION AMENDED. SEE ATTACHED SHEET

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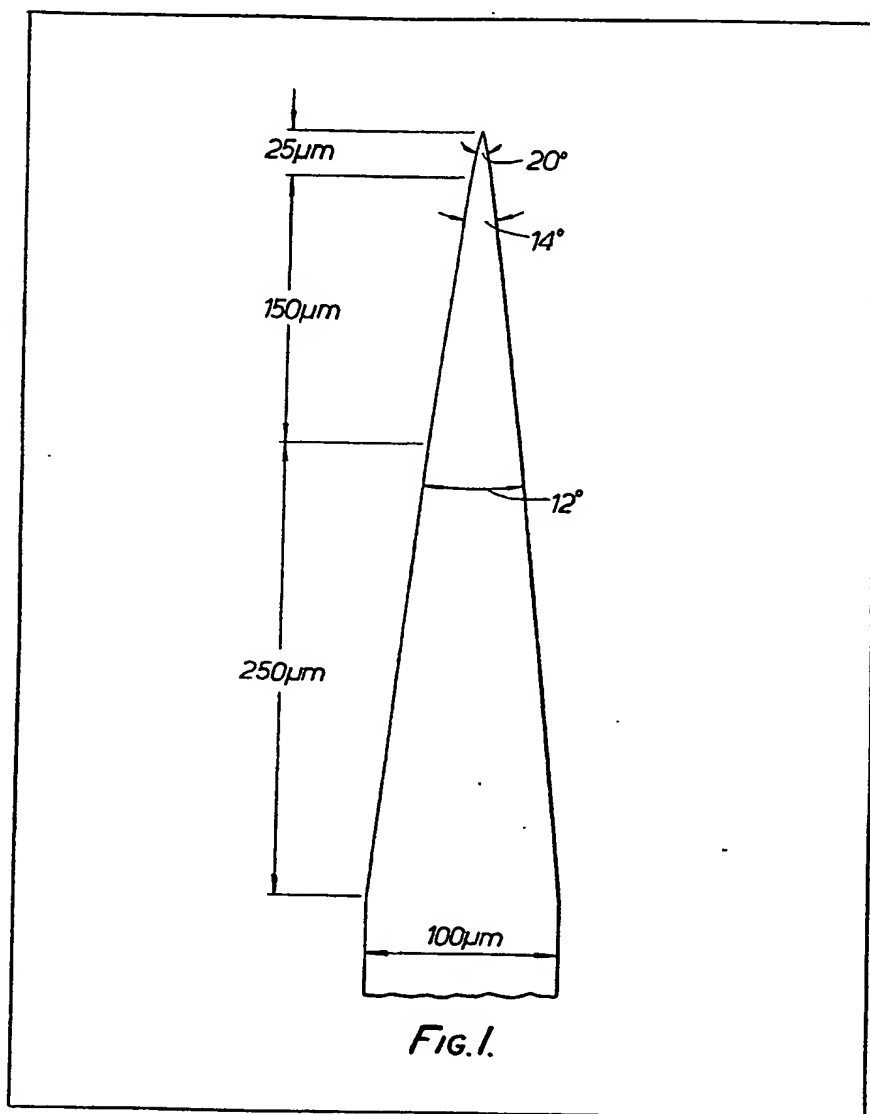
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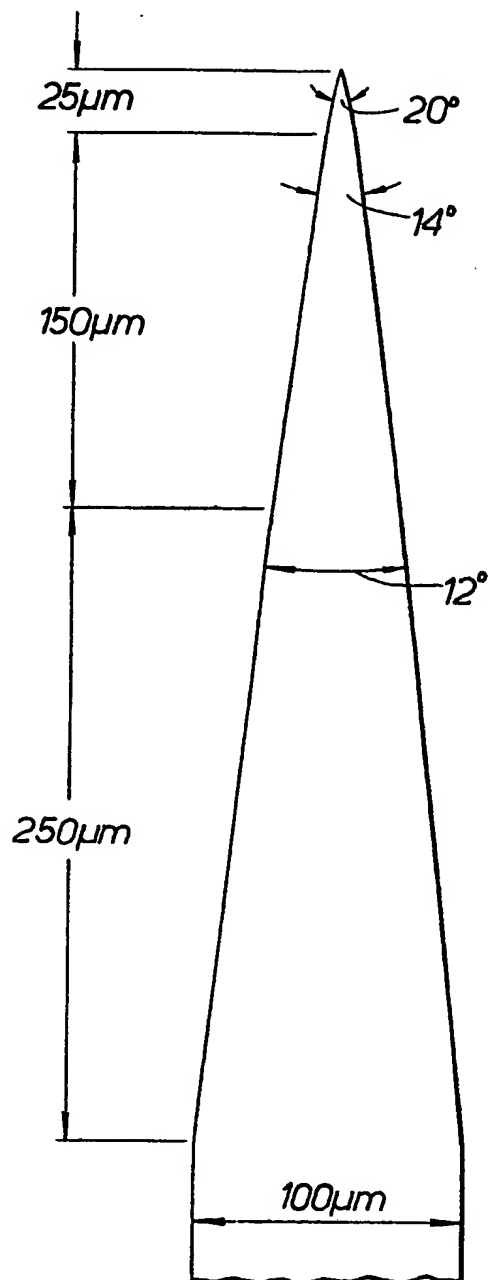


FIG. 1.

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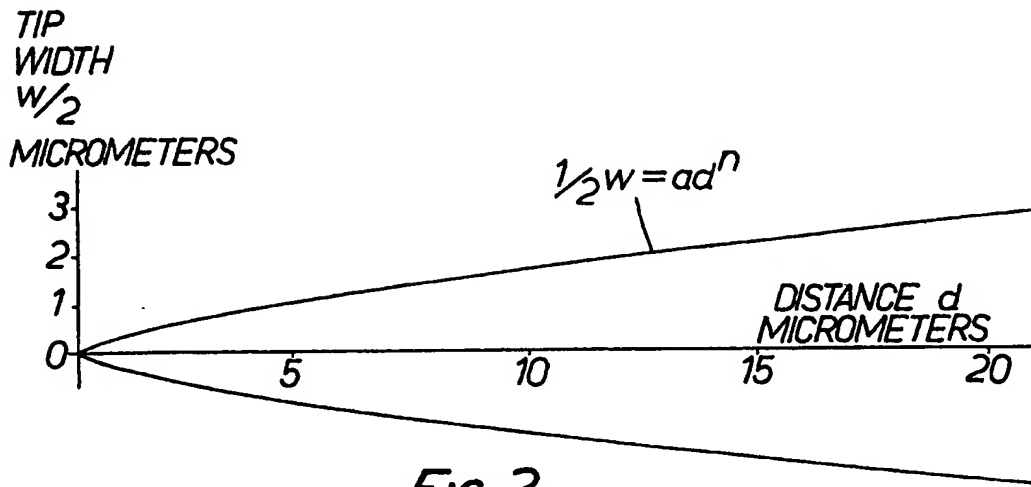


FIG.2.

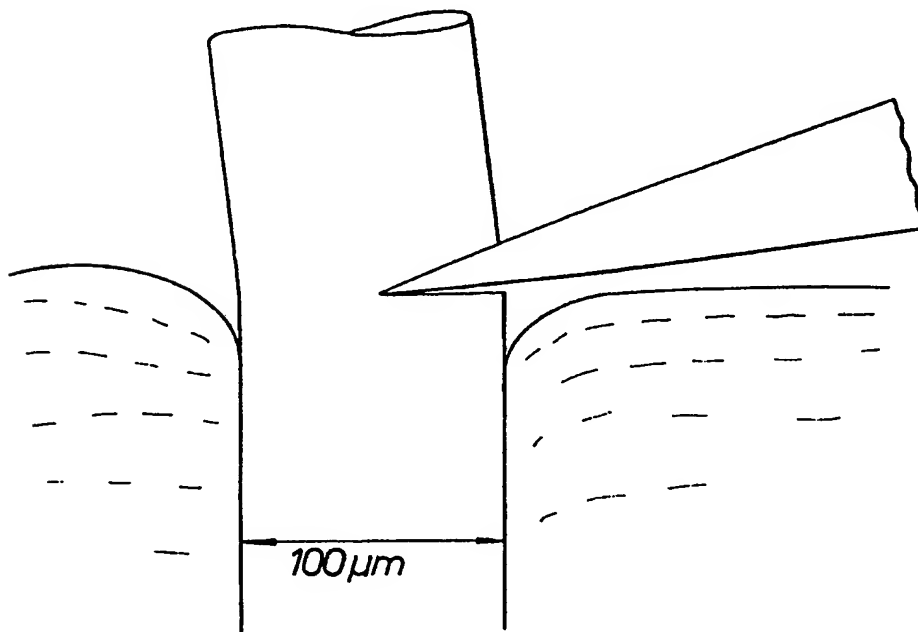


FIG.3.

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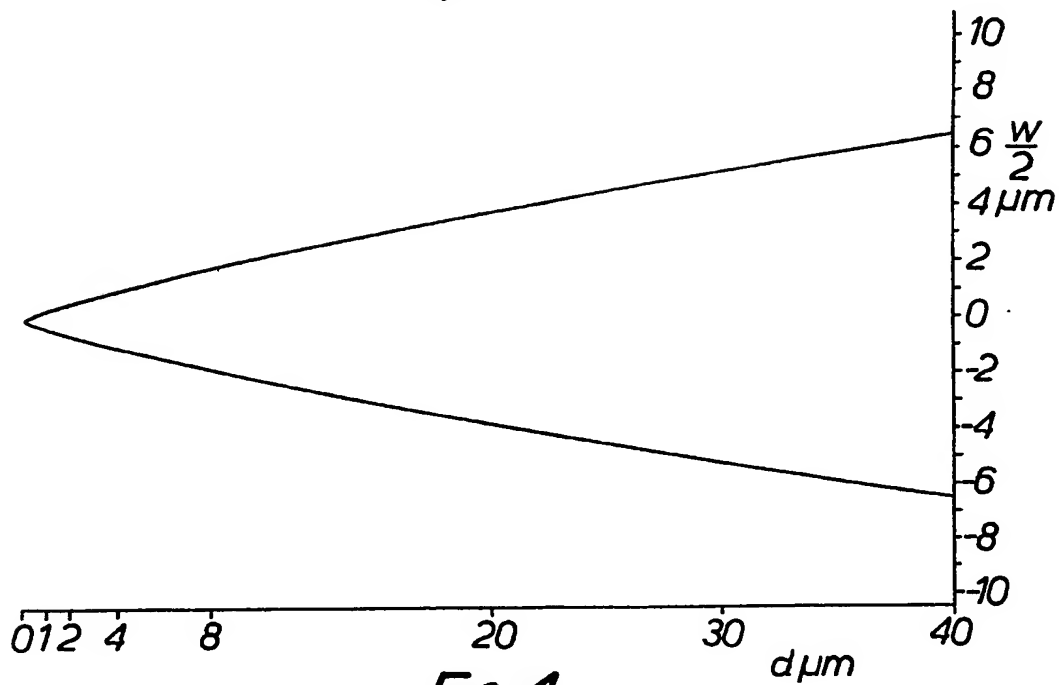


FIG.4.

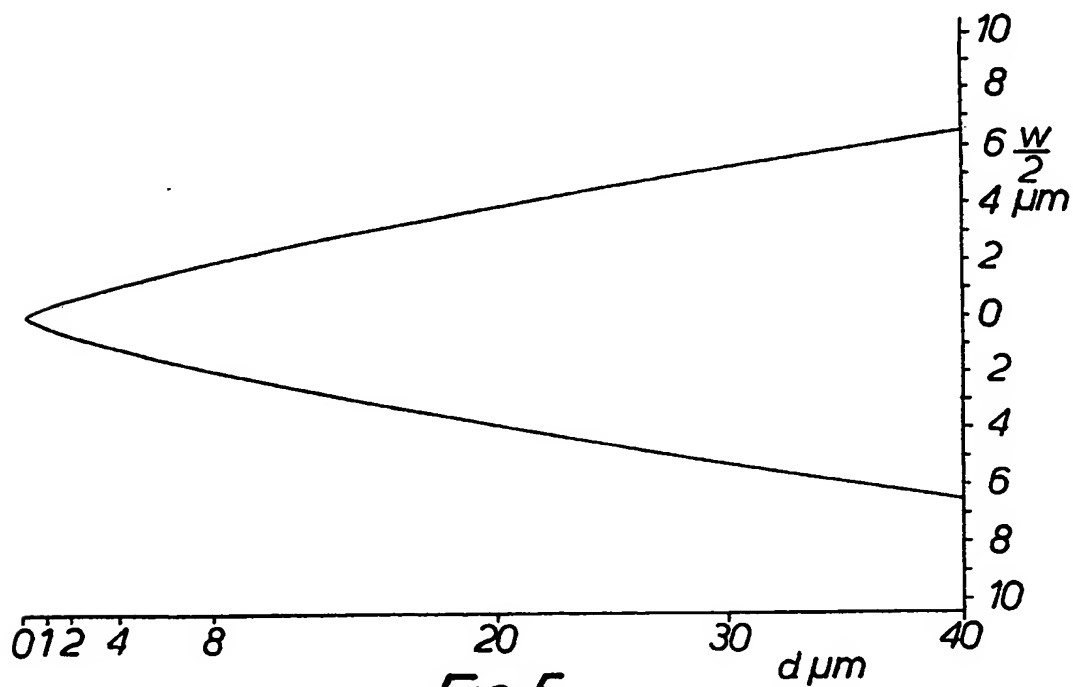


FIG.5.

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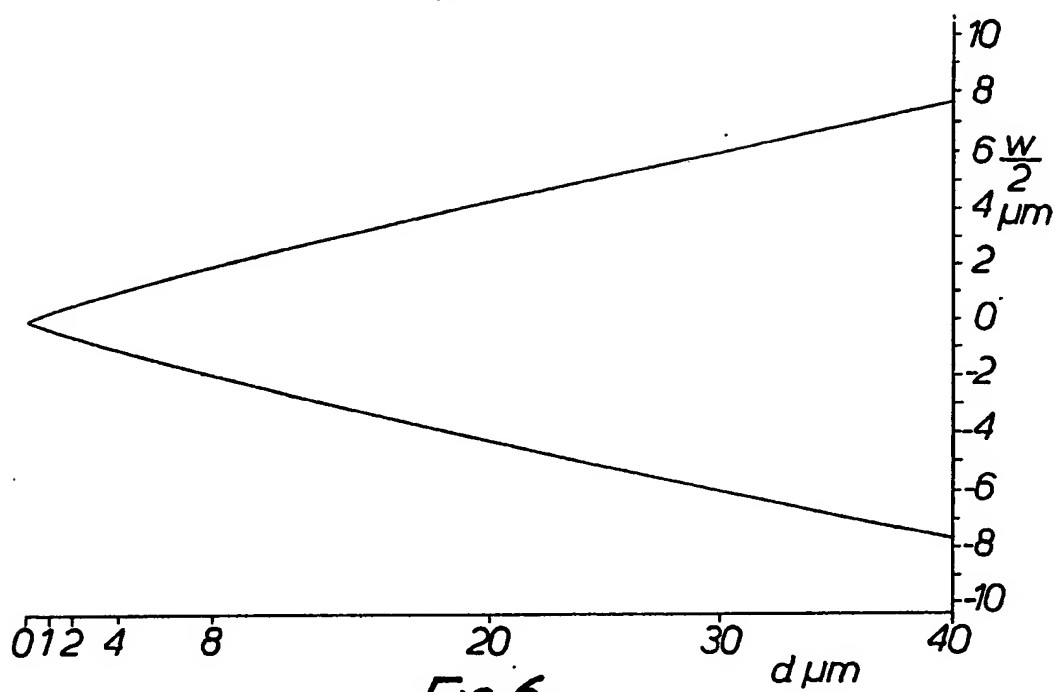


FIG. 6.

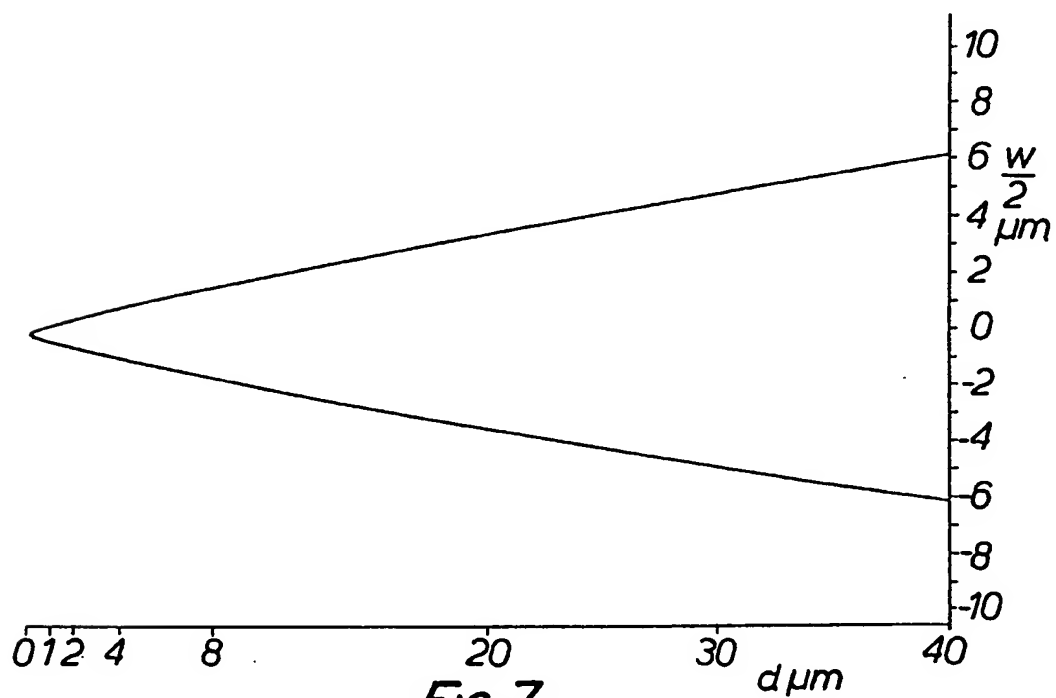


FIG. 7.

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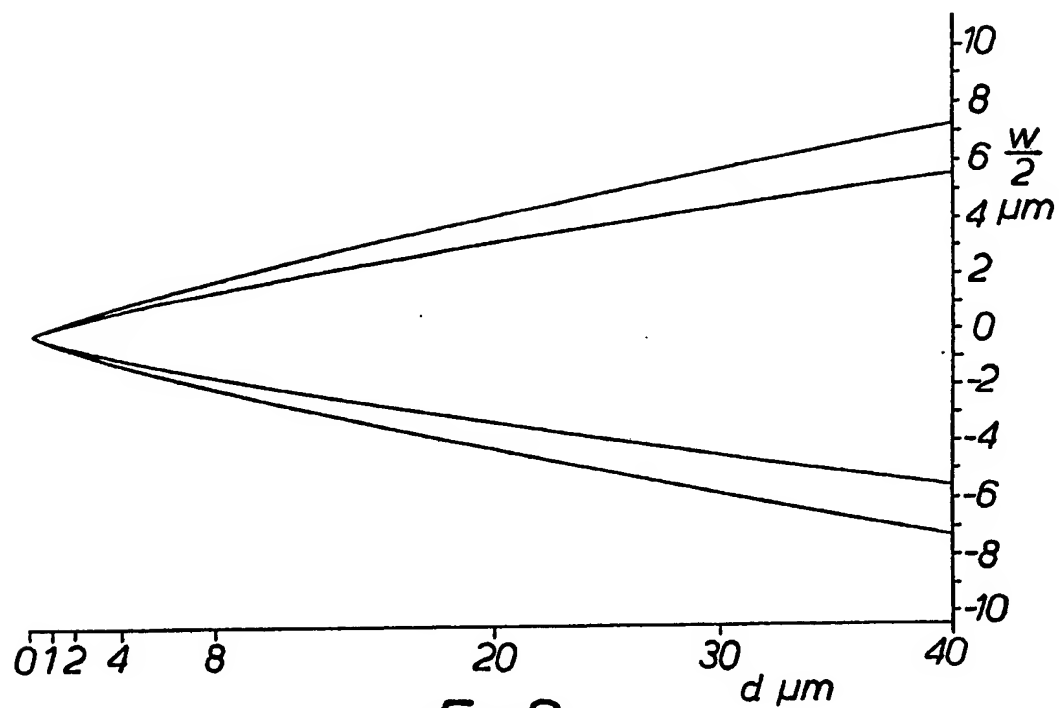


FIG. 8.

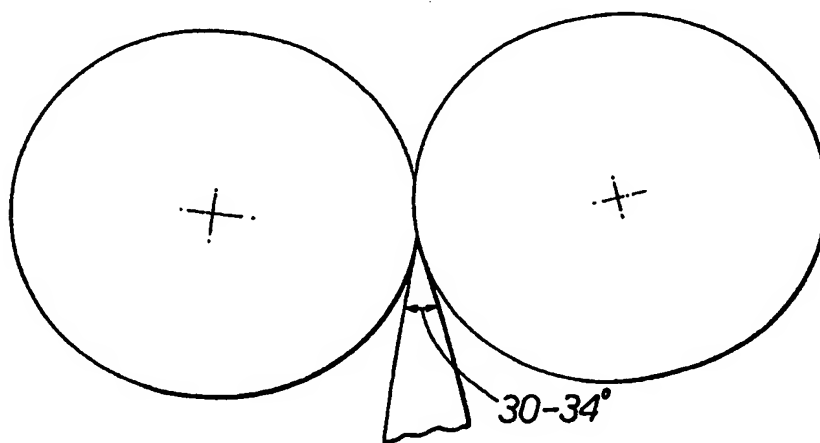
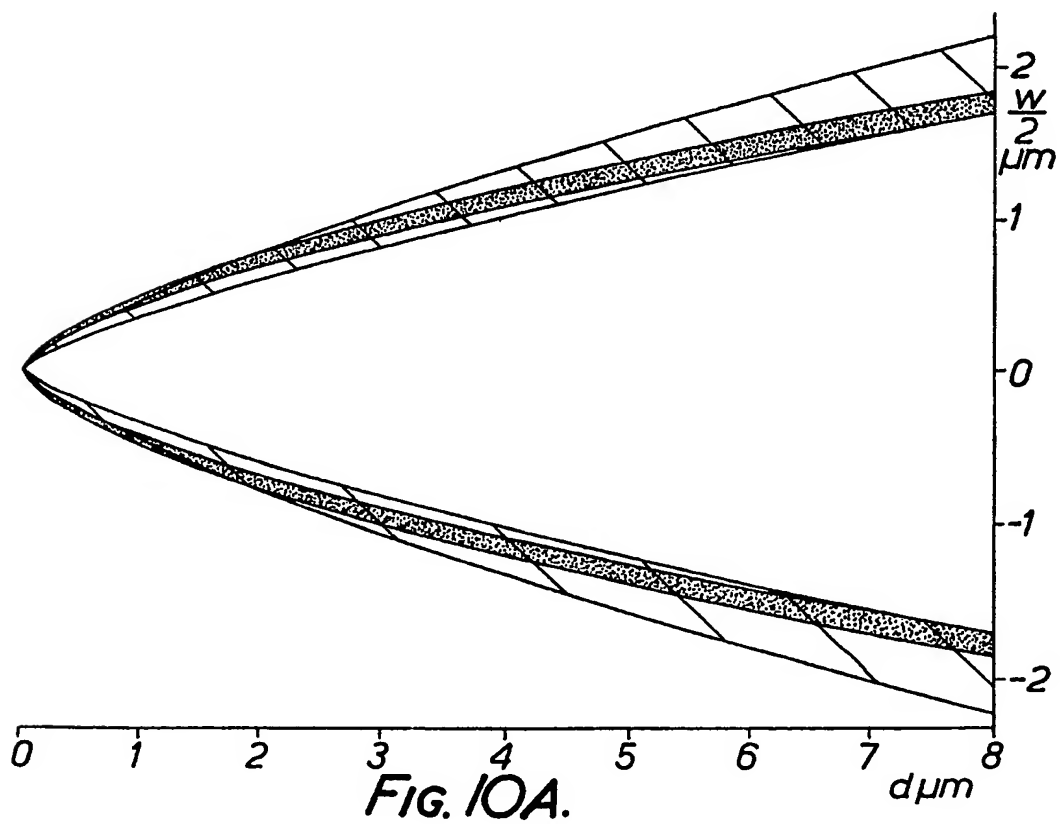
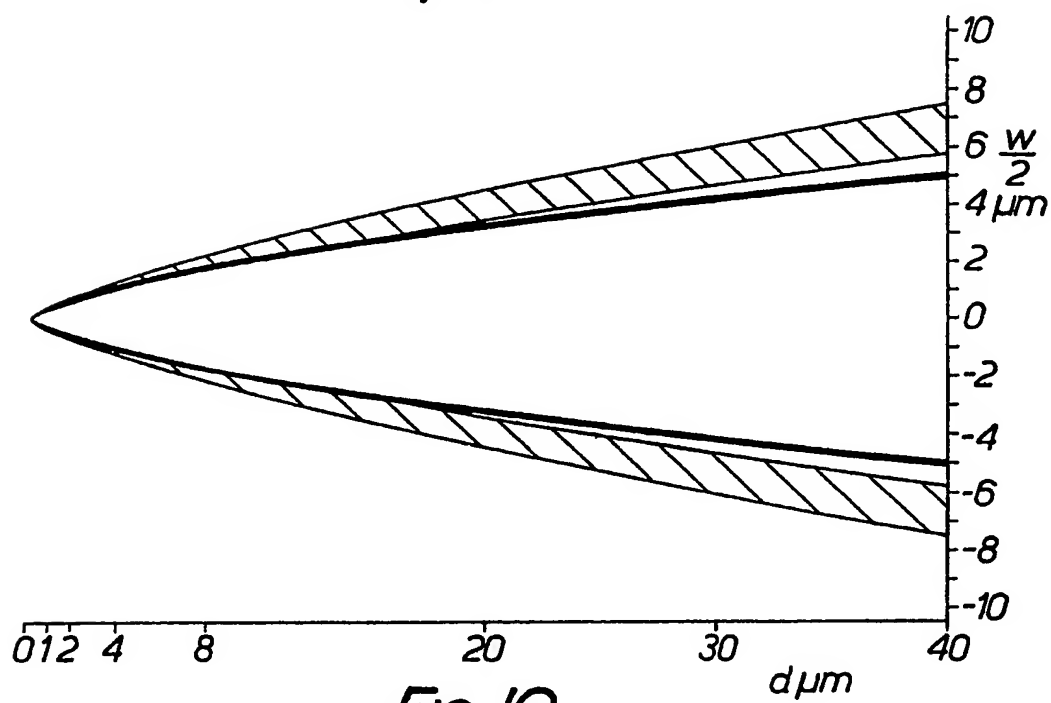


FIG. 9.

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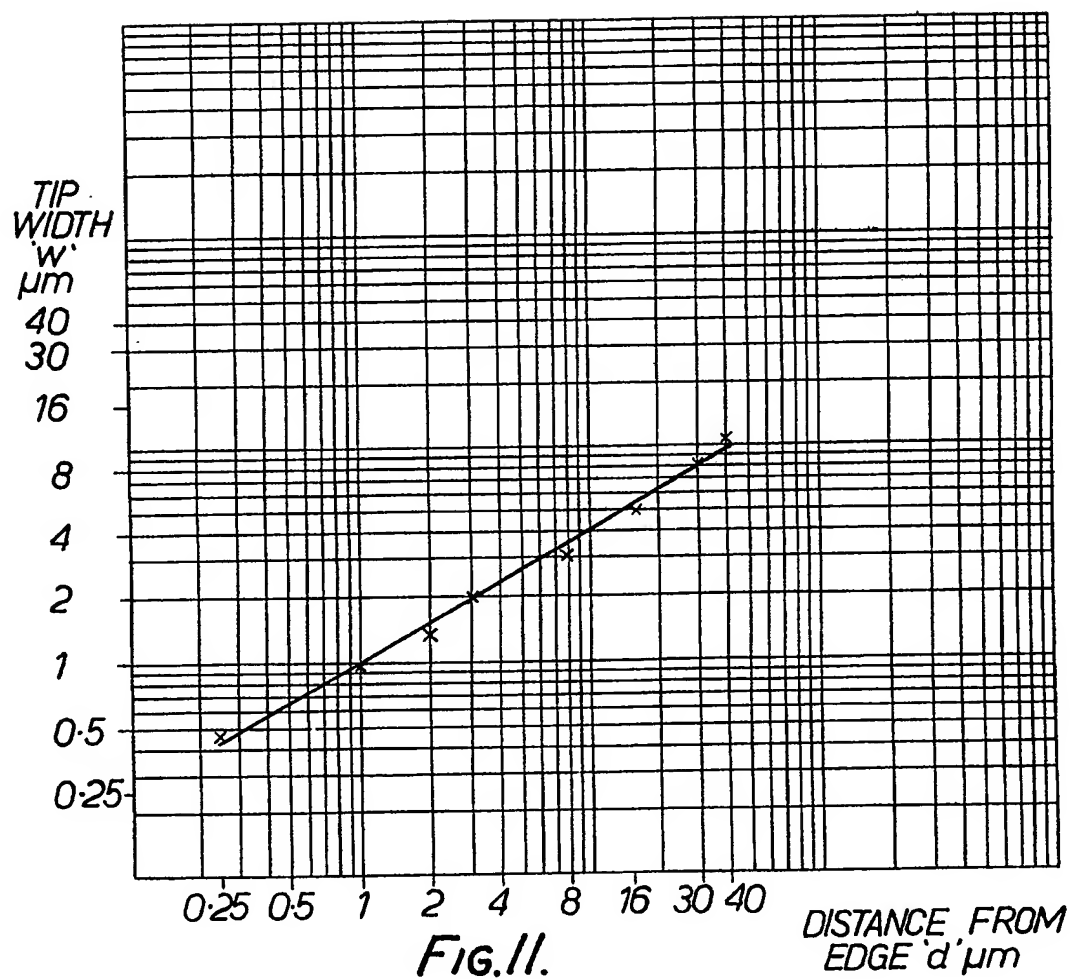
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# **SPECIFICATION** **Razor blades**

This invention relates to razor blades and is particularly concerned with the shaping of the cutting edge.

The invention resides broadly in a razor blade having a cutting edge the cross-sectional shape of which within the first 40  $\mu\text{m}$  measured back from the extreme edge is defined by the formula

$w = ad^n$  wherein  $d$  is the distance from the tip in  $\mu\text{m}$ ;  $w$  = the tip width (or thickness) in  $\mu\text{m}$  at a given distance  $d$ ;  $a$  is a factor of proportionality not greater than 0.8 and  $n$  is an exponent having a value less than 0.75, and wherein the included angle between the tip facets in the region from 40  $\mu\text{m}$  to 100  $\mu\text{m}$  from the extreme edge is within the range  $7^\circ$ — $14^\circ$  and preferably  $9^\circ$  to  $11\frac{1}{2}^\circ$ .

In the case of a stainless steel blade  $n$  is in the range 0.65 to 0.75 and  $a$  is in the range 0.70—0.80.

It has been found that blades having these tip characteristics provide improved shaving on comparative shave testing, but are sufficiently strong to give a reasonable useful life.

In order to convey a proper understanding of the nature of the present invention, it is convenient to describe and illustrate the background prior art in some detail. In the accompanying drawings:

Figure 1 is a greatly magnified view of a blade tip of typical, or average shape;

Figure 2 is a tip shape diagram illustrating the principle of "chord-width" measurement;

Figure 3 is a highly diagrammatic representation of the cutting of a facial hair;

Figures 4 to 7 are cross-sections of various respective blades currently marketed by a variety of manufacturers;

Figure 8 is a view, like Figures 4 to 7, of the tip shapes described in British Patent Specification 1465697.

Cutting edges on razor blades are sharpened by grinding a succession of pairs of facets (usually three) of different included angles onto a strip of steel by means of suitably arranged abrasive wheels. The cross-section through such an edge is illustrated in Figure 1 with typical values for dimensions and angles shown, and is customarily described as a "3-facet edge". While the final pair of facets is being ground (this stage is usually called "honing"), strip deflection in the sharpening machine together with the mechanical interaction between the steel and the abrasive particles of the wheel, produces final facets which are usually not planar but slightly convex. The curvature is a function of the type of steel and abrasive wheel used, as well as the sharpening machine setting parameters. Because of this convexity of the final facets, the blade tip cross section in this region is customarily referred to as "Gothic arched". The curvature prohibits precise geometrical definition of this part of the blade tip by means of a single parameter so that it is usual to characterise the shape by defining "tip" or "chord" widths at

various distances back from the edge. An alternative method is to ascribe a mathematical equation to fit the form of each half of the facet cross-section. These methods are illustrated in Figure 2.

During use, a razor blade is held in the razor at an angle of approximately  $25^\circ$ , and with the edge in contact with the skin, it is moved over the face so that when the edge encounters a beard hair, it enters and severs it by progressive penetration, aided by a wedging action. It is believed that the cut portion of the hair (which is on average about 100  $\mu\text{m}$  diameter) remains pressed in contact with the blade facets remote from the facial skin surface for a penetration up to only about half the hair diameter. Beyond this, the hair can bend and contract away from the blade to relieve the wedging forces. The resistance to penetration through reaction between hair and blade facets therefore occurs only over about the first 50  $\mu\text{m}$  of the blade tip back from the edge and the geometry of the blade tip in this region is regarded as being the most important from the cutting point of view. This is illustrated in Figure 3.

It is clear that a reduction in the included angle of the facets would correspondingly reduce the resistance to continued penetration of the blade tip into the hair. However, if the included angle were reduced too much, the strength of the blade tip would be inadequate to withstand the resultant bending forces on the edge during the cutting process and the tip would deform plastically (or fracture in a brittle fashion, depending on the mechanical properties of the material from which it is made) and so sustain permanent damage, which would impair its subsequent cutting performance, i.e. the edge would become 'blunt' or 'dull'.

In order to design a suitable shape for the blade tip which is just strong enough to prevent such bending induced damage, an estimation has been made of the magnitude of the bending stresses imposed during the severing of a hair. From these values and a knowledge of the yield strength of the steel from which the blade is made, minimum dimensions can be calculated for the tip section. The stresses imposed during cutting were assumed to arise from the visco-elastic flow of saturated hair material past the blade tip.

Blades currently produced have tip geometries with some dimensions which are below these minimum values and are known to become dulled by edge bending during the normal shaving life (which is on average, approximately 10 days for a blade made from conventional razor blade stainless steel).

We have now found that by careful control of the tip geometry in specific regions 0—40  $\mu\text{m}$  from the edge, the overall cross-section can be reduced so that cutting performance and shaving satisfaction are improved, while retaining adequate strength to resist edge bending damage and so maintain acceptable durability.

The tip shapes of various manufacturers blades currently on the market are shown in Figures 4 to 7.

7, and Figure 8 illustrates blade tip forms as described in British Patent 1 465 967.

These known blade tip shapes are compared with the preferred blade tip shape of the present invention in Figures 10 and 10A.

In one form of the present invention, the blade tip cross-section is first narrowed by grinding the three facets to smaller included angles than those typified in Figure 1. This produces a blade tip whose cross-section is generally narrower throughout and, importantly, in the 0—40  $\mu\text{m}$  distance back from the edge, which is of particular interest during hair cutting. Such an edge is too weak to withstand stresses during shaving and must be further modified. This is achieved by adding what amounts to a fourth sharpening stage. It is carried out using rotating interlocking discs or spirals of leather or synthetic leather (usually called "strops"), with abrasive material added to their peripheries. The sharpened blades pass between the strops, which polish the facets, removing a small amount of steel from their surfaces, and so changing the "Gothic arch" dimensions. This stage is called "abrasive stropping". Because of the flexibility of the strop leather, allowing it to conform somewhat to the sharpened blade tip, abrasive stropping increases the curvature of the final facet, close to the edge, while having less effect on the facet shape further back.

It has been found that when blades are sharpened with suitably reduced facet included angles, followed by an appropriate abrasive stropping treatment, the tip shape is changed so that the chord widths close to the edge become larger than those on conventionally sharpened edges, while the chord widths further away from the edge remain smaller than those on conventionally sharpened edges. This results in the blade tip close to the edge being stronger than normal, so that it can better resist the bending stresses imposed on it during hair cutting, while the reduced section further back from the edge, presents less resistance to penetration during hair cutting, so facilitating the cutting process.

The ultimate tip radius of the edge should be conventional, with an average value of less than 1000 $\mu\text{A}$  and preferably less than 500 $\mu\text{A}$  as stated, for example, in Patent Specification 1,378,550 (U.S. 3,761,374), that is, within the normal range for conventionally sharpened edges.

Blades in accordance with the invention have been found to have superior shaving performance when compared with conventional blades on a standard shaving test.

One form of blade in accordance with the invention and the manner in which it is formed are described in detail below, by way of example, with reference to Figures 9, 10 and 11, in which:

Figure 9 is a diagrammatic illustration of a blade tip stropping operation;

Figures 10 and 10A are representations of blade tip forms in accordance with the invention, compared with the known blade tip forms seen in Figures 4 to 8. Figure 10A is a detail from Figure 10 on a larger scale; and

Figure 11 is a graph of chord widths 'w' at different distances 'd' plotted on logarithmic scales.

Stainless steel razor blade strip, of nominal composition 13% Cr, 0.6% C, was hardened and tempered in accordance with conventional practice, and sharpened by grinding and honing to produce edges of three facet configuration, as illustrated in Figure 1, but with included angles smaller than those conventionally manufactured. The blades were passed between rotating strops of artificial leather, whose surfaces contained fine alumina abrasive, in the manner of conventional abrasive stropping, where the angle set on the strops (which is the included angle between the tangents to the strops at their point of intersection, as shown in Figure 9) was in the range 30°—34°. The facets were provided with a metallic coating of an alloy of chromium and platinum (applied in accordance with Patent U.S. 3,829,969) with a superimposed coating of fluorocarbon material (such as described in British Patent 906,005).

The processes of grinding, honing and stropping are well known in the art, but it will be understood that less conventional methods could be employed for sharpening the tip, e.g. deforming the strip between appropriately shaped dies or rollers, or by electrolytic or chemical dissolution shaping or by ion bombardment shaping.

The blade tip cross-sections were measured using optical interferometry. A blade is placed under the objective lens of a metallurgical microscope fitted with a Michelson type interferometer and viewed at a magnification of about 1000 $\times$ . The interferometer is adjusted to produce fringes which are oriented at right angles to the edge of the blade. The blade is tilted at an appropriate angle so that the fringes are displaced to reveal the topography of the blade facets. The fringe spacing is adjusted so that fringe displacements can be readily measured at various distances back from the edge. Knowing the angle of tilt, the tip shape is calculated from the sum of these fringe displacements, measured at corresponding positions on each side of the blade.

The results of these measurements are shown in Figure 10, in which the spread of profiles of the preferred blade tips over the first 40  $\mu\text{m}$  are shown by solid shaded bands, and the spread of profiles of known blades is indicated by the cross-hatched bands.

In this specific example, the chord widths w at distances d from the extreme edge were as set out below:—

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	$d$ ( $\mu\text{m}$ )	$w$ ( $\mu\text{m}$ )
	0.25	.20—.30
	0.5	.34—.50
	0.75	.53—.72
5	1.0	.71—.92
	2.0	1.17—1.37
	4.0	1.86—2.16
	8.0	3.05—3.52
	20.0	6.12—6.85
10	30.0	8.43—9.52
	40.0	10.73—12.11

The geometry of this profile was re-plotted on a graph using logarithmic scales for tip thickness as a function of distance from the edge and the resultant plot is shown in Figure 11, from which it is seen that a straight line can be fitted to the plotted points.

From the slope and intercept of the straight line, the tip shape can be defined by the equation  $w = ad^n$  in which  $a$  is a factor of proportionality not greater than 0.8 and  $n$  an exponent having a value of not more than 0.75, and more specifically within the range 0.65—0.75.

The known blades measured were found to have best fit straight lines with exponents (or gradients) within the range 0.76—1.0.

The smaller gradient is a primary characteristic of the present invention and results in the fact that the blade tip of the present invention, compared with those of the prior art, is relatively thick and strongly arched close to the extreme edge, but relatively thin over the remainder of the tip.

The included facet angles in the region 40—100  $\mu\text{m}$  from the tip are in the range  $9^\circ$  to  $11\frac{1}{2}^\circ$  but making due allowance for manufacturing tolerances could be in the range  $7^\circ$  to  $12^\circ$  or even  $7^\circ$  to  $14^\circ$ .

It must be appreciated that the tip shapes described above are for stainless steel blades and could be made substantially thinner for harder blade materials such as sapphire, titanium carbide or diamond.

To produce an equivalent tip shape from a material harder than stainless steel, we reduce the corresponding chord widths in inverse proportion to the square root of the yield strength of the harder material in comparison with stainless steel. In the case of diamond, for example, the chord widths would be approximately 40% of those calculated for stainless steel.

Furthermore, the tip region of a stainless steel blade may be coated with a material harder than

stainless steel and having a higher yield strength. In such a case the chord widths given by the basic equation are reduced by adopting the modified formula:

$$w \geq \frac{1}{\sqrt{m}} a \cdot d^n$$

In which  $m$  is the ratio of the yield strength of the coating material to that of stainless steel.

Furthermore, in order to ensure the integrity of the steel substrate, the value for  $w$  must also satisfy the equation  $W^3 \geq (W - 2h)a^2d^{2n}$ , where  $h$  is the thickness of the coating.

It will be understood by those skilled in the art that the blade tips may, in each case, be coated with materials such as p.t.f.e., which further enhance the cutting action. The thicknesses of such coatings are, of course ignored for the purposes of calculating the tip chord widths.

## CLAIMS

1. A razor blade having a cutting edge tip of stainless steel, the cross-sectional shape of which up to a distance of 40  $\mu\text{m}$  from the extreme edge is defined by the equation:

$$w = ad^n$$

in which  $w$  is the chord thickness in  $\mu\text{m}$  of the tip at a distance  $d$  in  $\mu\text{m}$  from the extreme edge of the blade;  $a$  is a factor of proportionality not greater than 0.8 and  $n$  is an exponent having a value in the range 0.65 to 0.75.

2. A razor blade according to claim 1, modified in that the tip at least of the blade is of a material which has a higher yield strength than stainless steel, wherein the width  $w$  obtained from the said equation is reduced in inverse proportion to the square root of the ratio of the yield strength of the harder material to that of stainless steel.

3. A razor blade according to claim 1, modified in that the cutting edge tip is coated with a material having a greater yield strength than stainless steel, wherein the cross-sectional shape of the tip is defined by the equation

$$W \geq \frac{1}{\sqrt{m}} a \cdot d^n$$

In which  $m$  = the ratio of the yield strength of the hard coating to that of stainless steel, and wherein  $W$  also satisfies the equation:

$$W^3 \geq (W - 2h)a^2d^{2n},$$

in which  $h$  is the thickness in  $\mu\text{m}$  of the coating.

4. A razor blade according to claim 1, wherein the blade tip is formed with facets at a distance between 40 and 100  $\mu\text{m}$  from the extreme edge which facets converge towards the edge at an

4

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Included angl in the range  $7^{\circ}$ — $12^{\circ}$  and preferably  $9^{\circ}$  to  $11\frac{1}{2}^{\circ}$ .

5. A razor blade having a cutting dge tip of

stainless steel in which the cross-sectional shap  
5 of th tip is as defined by the specific exampl  
herein.

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